

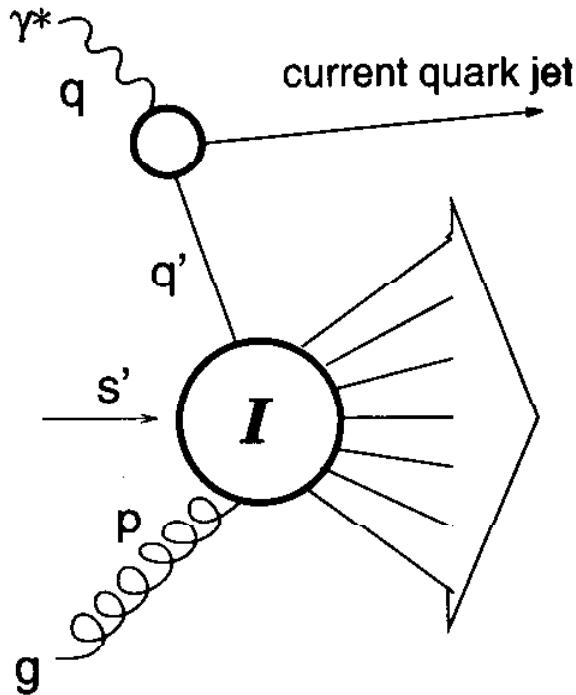
Confronting the QCD Instanton to HERA Data

T. Carli, M. Kuhlen

Max-Planck Institut für Physik, Munich.

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Production of instantons at HERA



Variables in subprocess:

$$Q' = -q'$$

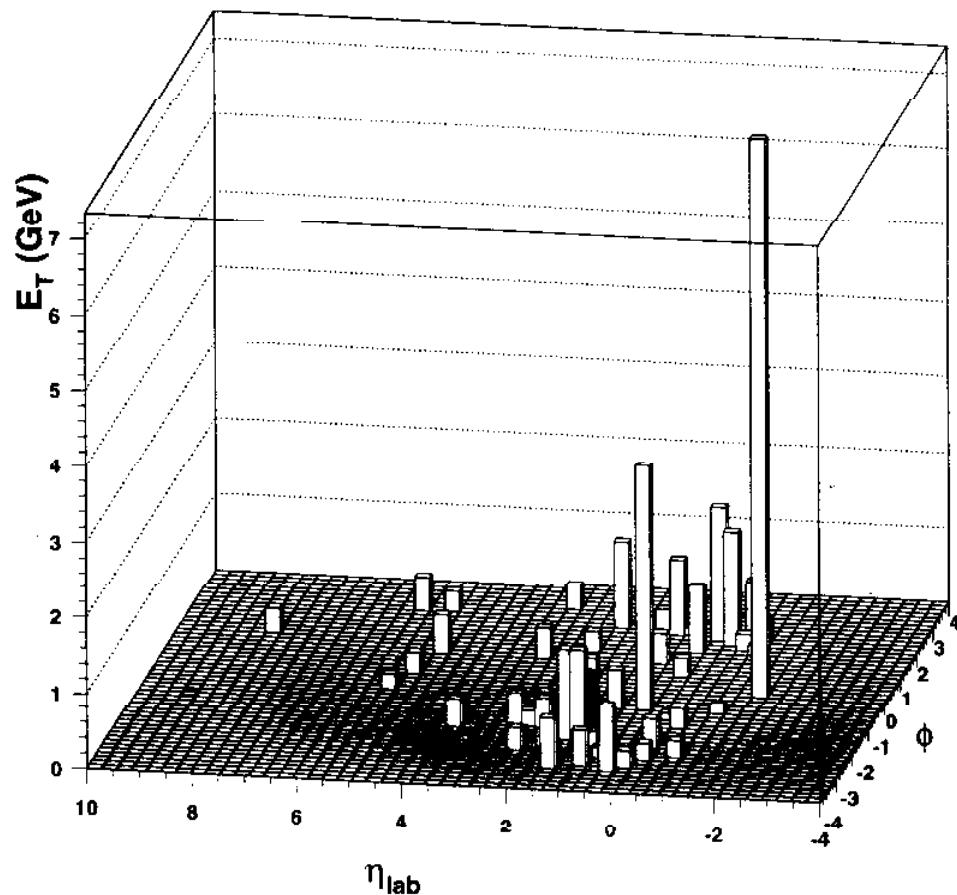
$$x' = Q'^2 / (2 p \cdot q')$$

$$\sigma_{q^* g} \sim \frac{1}{Q'^2} \left(\frac{4\pi}{\alpha^{\text{eff}}(Q'^2)} \right)^{\frac{21}{2}} \exp\left(\frac{4\pi}{\alpha^{\text{eff}}(Q'^2)} F(x')\right)$$

Q'^2 : controls hardness of subprocess
 \rightarrow strong influence on event topology

x' : needs to be large e.g. $x' > 0.2$
 to be model independant
 only weak influence on event topology

Signature of instantons at HERA



Instanton decays isotropically in multi-parton state
consisting of gluons and all quark flavours
kinematically allowed:

- High multiplicity
- densely populated narrow band in η , flat in ϕ
- more strange/charm particle than in normal DIS
- large transverse energy

Adressed Question

Instanton has distinct signature:

→ Investigate systematically instanton sensitivity to all available DIS data on hadronic final state

What is the maximally allowed proportion of instantons in the normal DIS sample ?

Simulation:

QCDINS1.3 (Gibbs et al.)

- hard subprocess (see A. Ringwald, DIS '97)
- leading log parton shower (as in HERWIG)
- hadronisation (as in HERWIG)

ARIADNE 4.08 (Lönnblad)

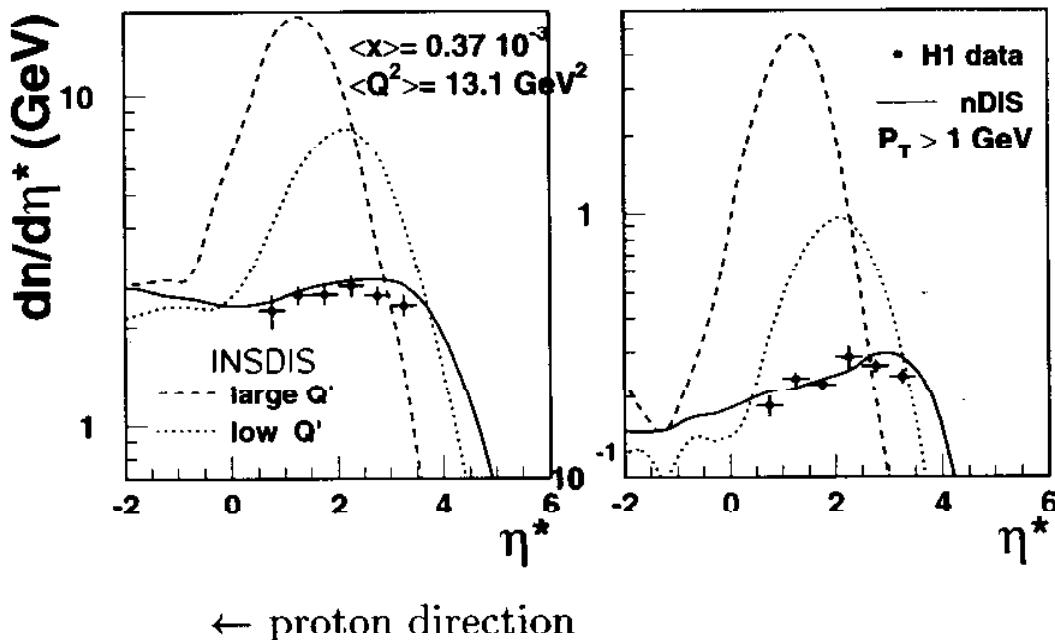
- leading order matrix element
- colour dipole model
- hadronisation (as in JETSET)

Note, ARIADNE gives excellent description of DIS data, see e.g. T. Carli, DIS '96 or HERA workshop '96

Charged Particle multiplicity flow

Proton-Photon center of mass frame:

H1 Data Nucl.Phys. B485 (97)



particles/per rapidity unit:

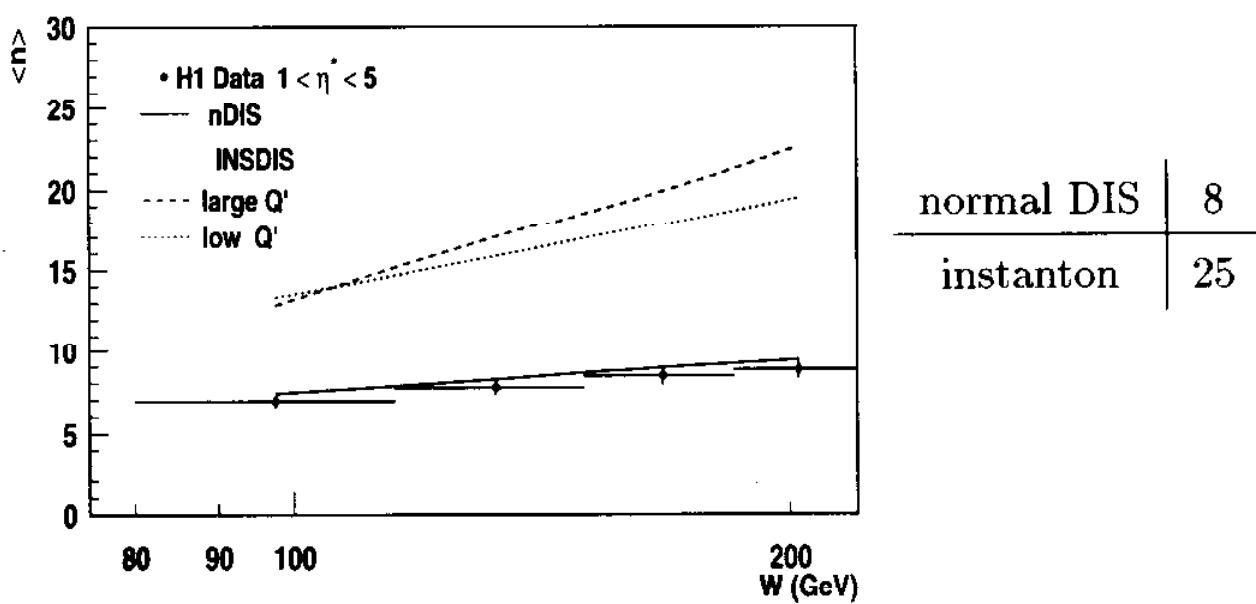
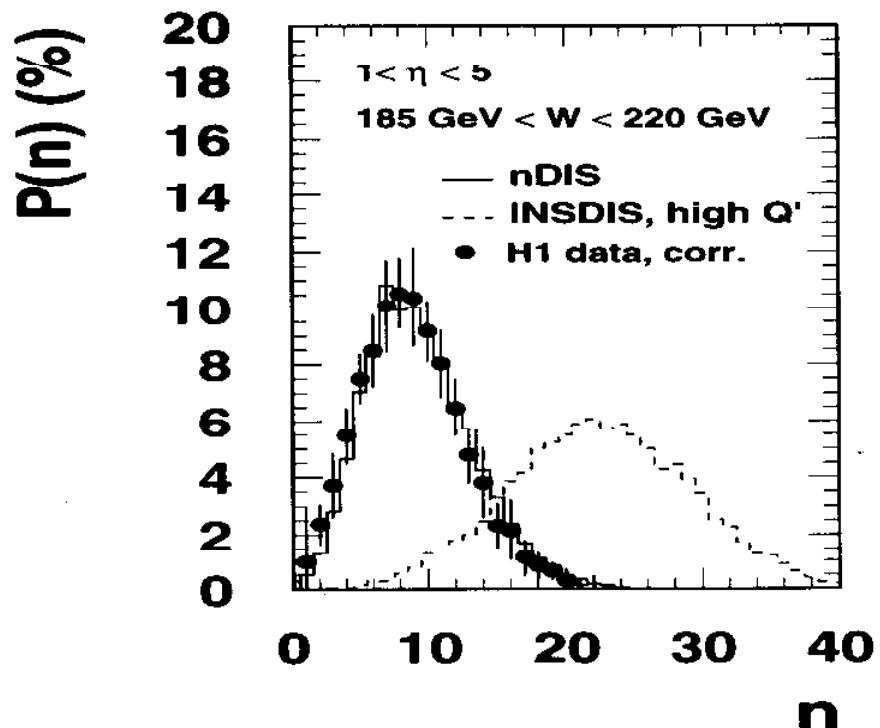
normal DIS	2
instanton	15

For increasing Q'^2 :

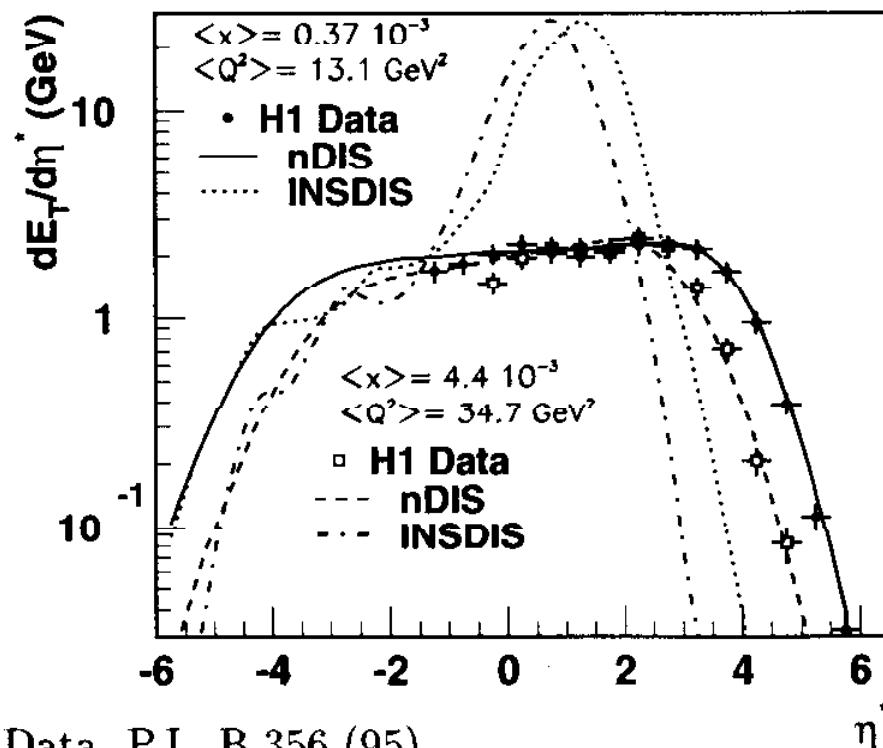
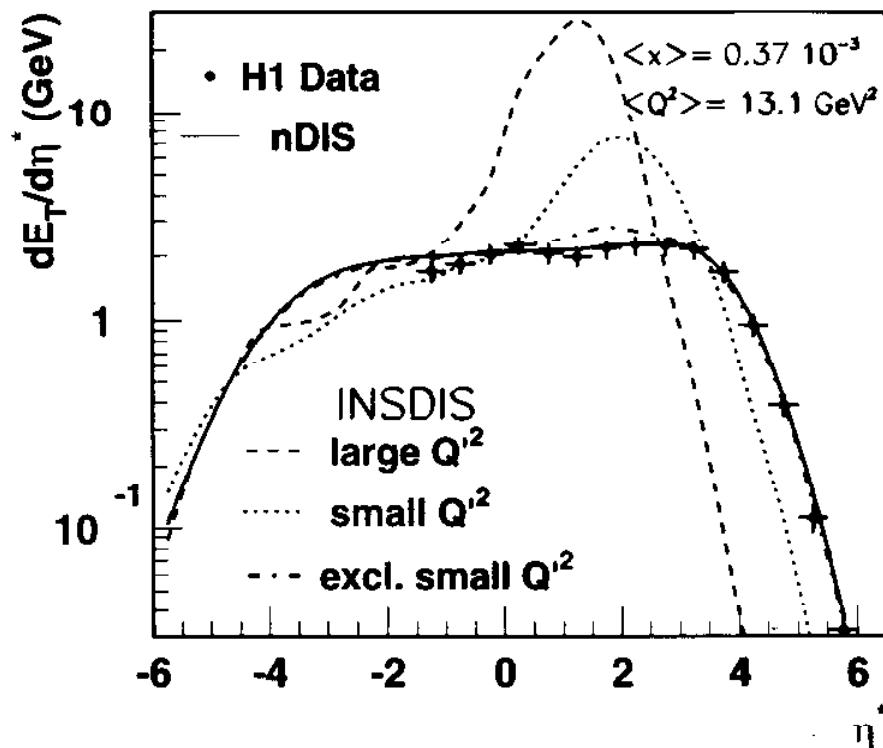
- band moves forward
- instanton get harder

Charged Particle Multiplicity Distribution

H1 Data Z. Phys. C72 (96)



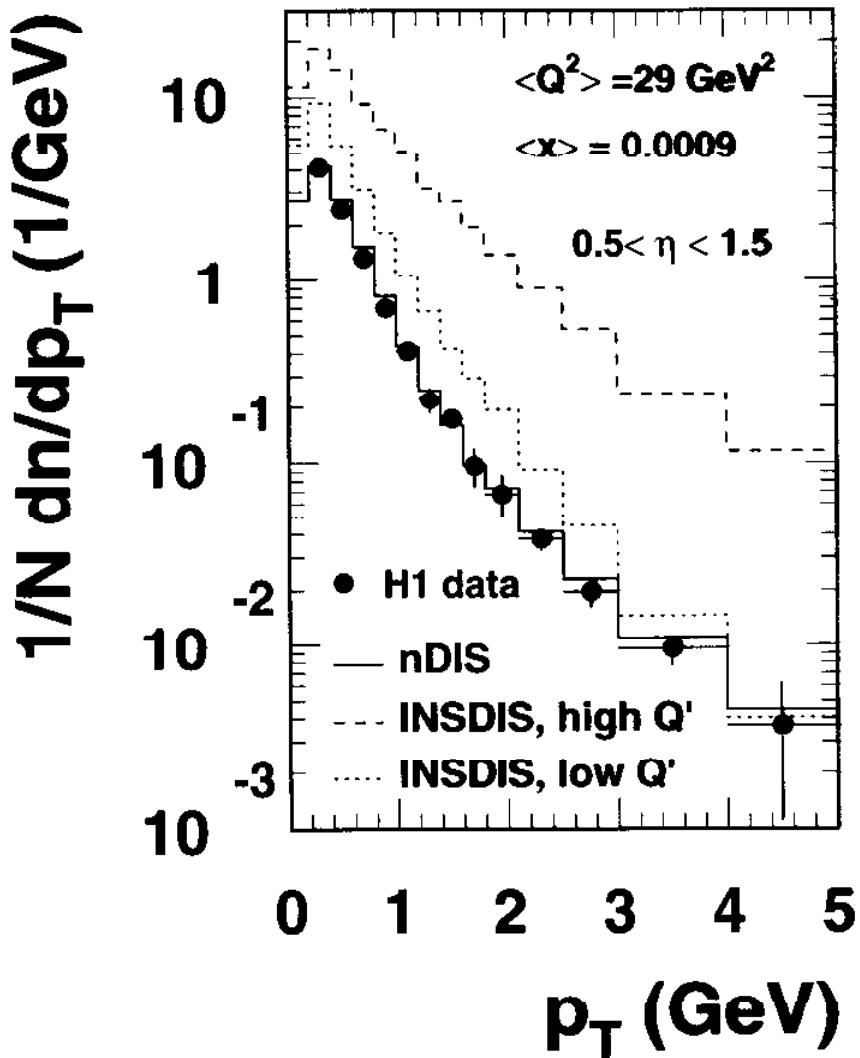
Transverse Energy Flow



H1 Data P.L. B 356 (95)

Increasing Q'^2 : harder and moves forward

Transverse Momentum Distribution of Charged particles



H1 Data Nucl.Phys. B485 (97)
large $Q' \rightarrow$ large P_T

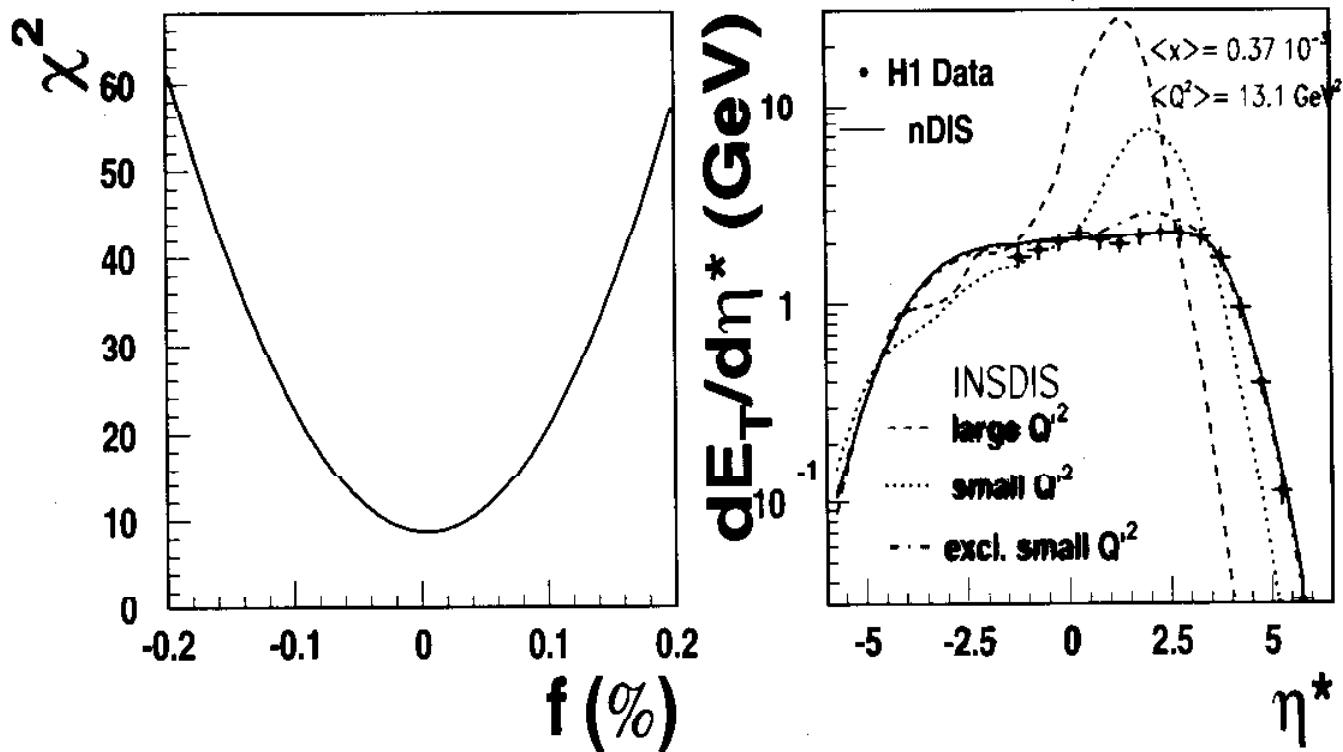
Extracting Allowed Instanton Fraction

Limits from event shapes using χ^2 technique:

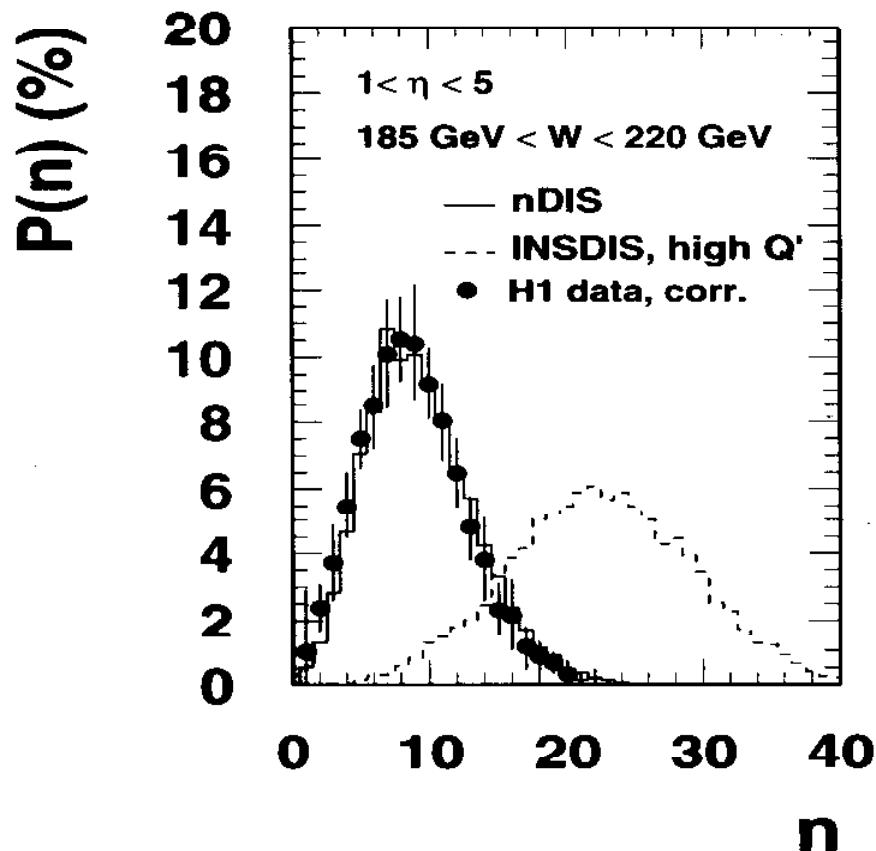
$$\chi^2 = \frac{1}{\text{nbin}} \sum_{i=1}^{\text{nbin}} \frac{(\text{MC}(i) - \text{Data}(i))^2}{\sigma_{\text{MC}(i)}^2 + \sigma_{\text{Data}(i)}^2} \quad (1)$$

$$\text{MC}(i) = f \text{ INSDIS}(i) + (1 - f) \text{ nDIS}(i) \quad (2)$$

\rightarrow from $\chi^2 \rightarrow 95\%$ read confidence limit



Limits from Multiplicity Distribution



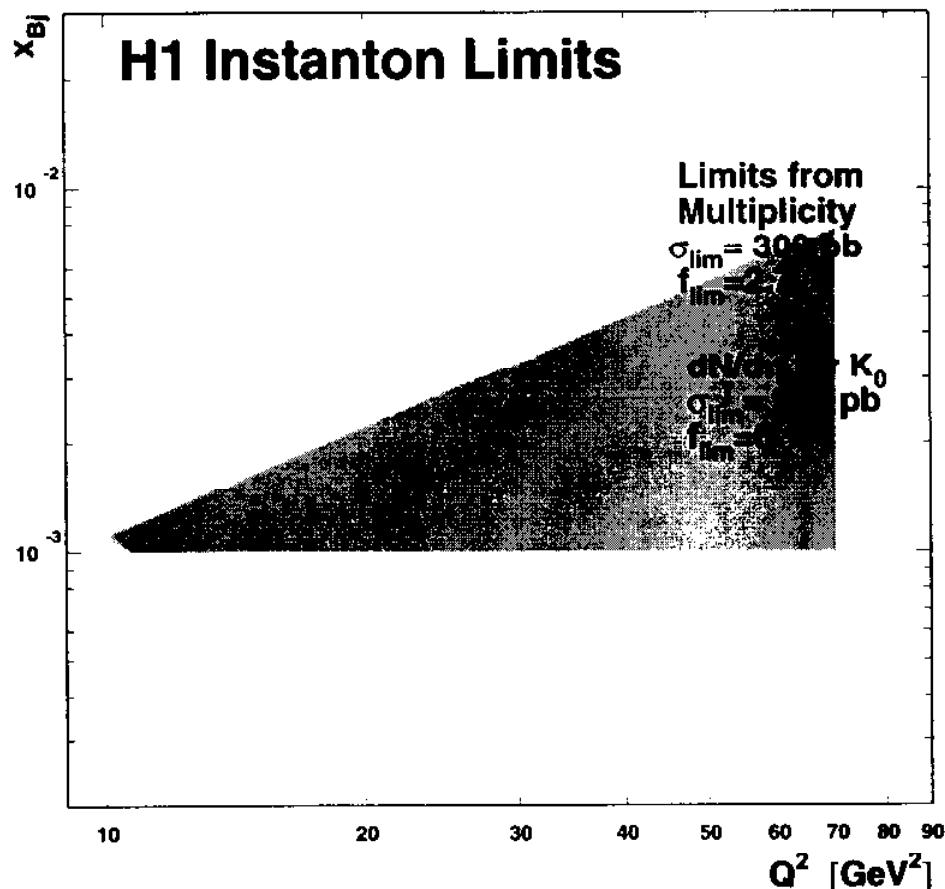
Determine n_{cut} beyond that no events have been measured:

Fractional limit (95% confidence limit):

$$f_I < f_{\text{lim}} = \frac{3/\varepsilon_I}{N_{\text{DIS}}}.$$

ε_I to detect instanton beyond n_{cut}

Limits Existing so far

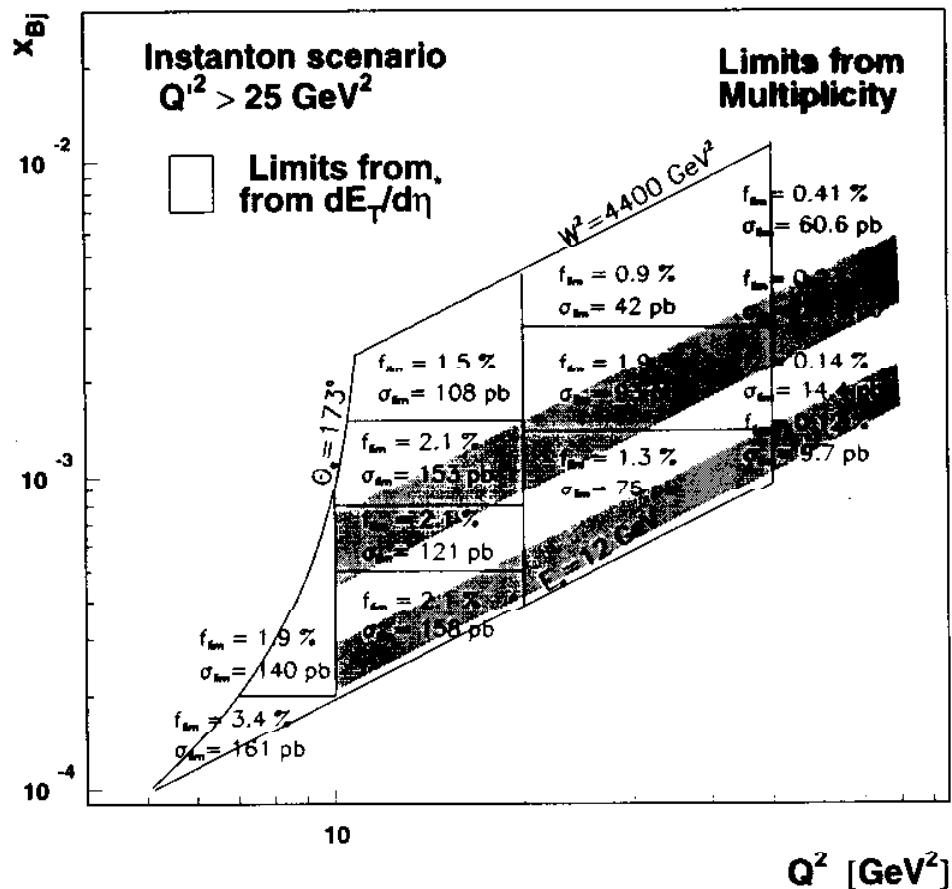


from Z. Phys. C72 (96) and Nucl.Phys. B480 (96)

This analysis:

- extent kinematic domain
- improve limits by order of magnitude

Limits for Large Q'^2



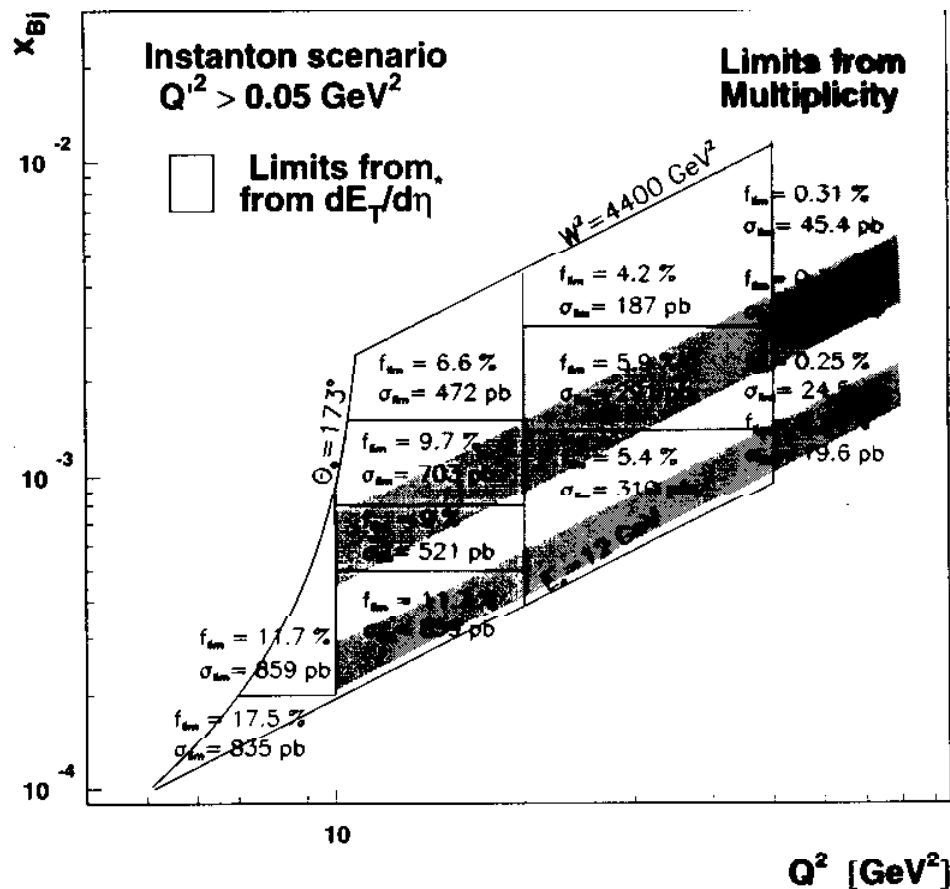
Transverse energy flow (event shape):

$$1 \lesssim f_{lim} \lesssim 3\% \quad 40 \lesssim \sigma_{lim} \lesssim 160 \text{ pb}$$

High multiplicity:

$$0.1 \lesssim f_{lim} \lesssim 0.4\% \quad 9 \lesssim \sigma_{lim} \lesssim 60 \text{ pb}$$

Limits for Low Q'^2



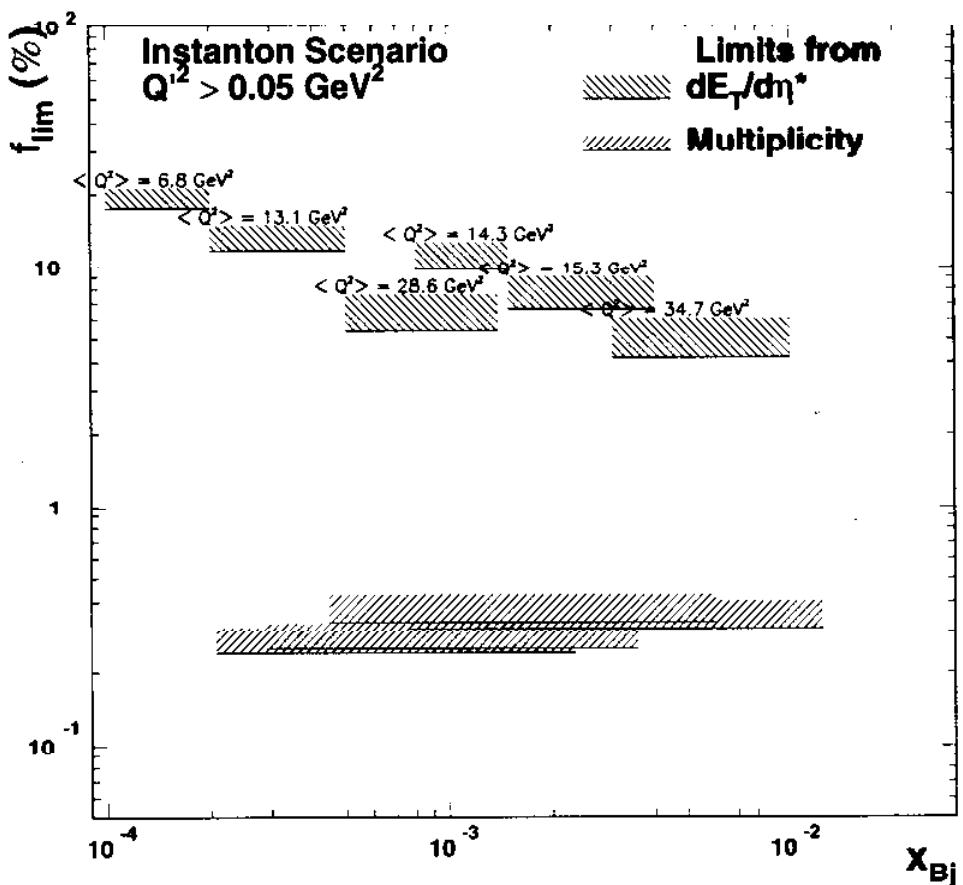
Transverse energy flow (event shape):

$$4 \lesssim f_{lim} \lesssim 18\% \quad 180 \lesssim \sigma_{lim} \lesssim 860 \text{ pb}$$

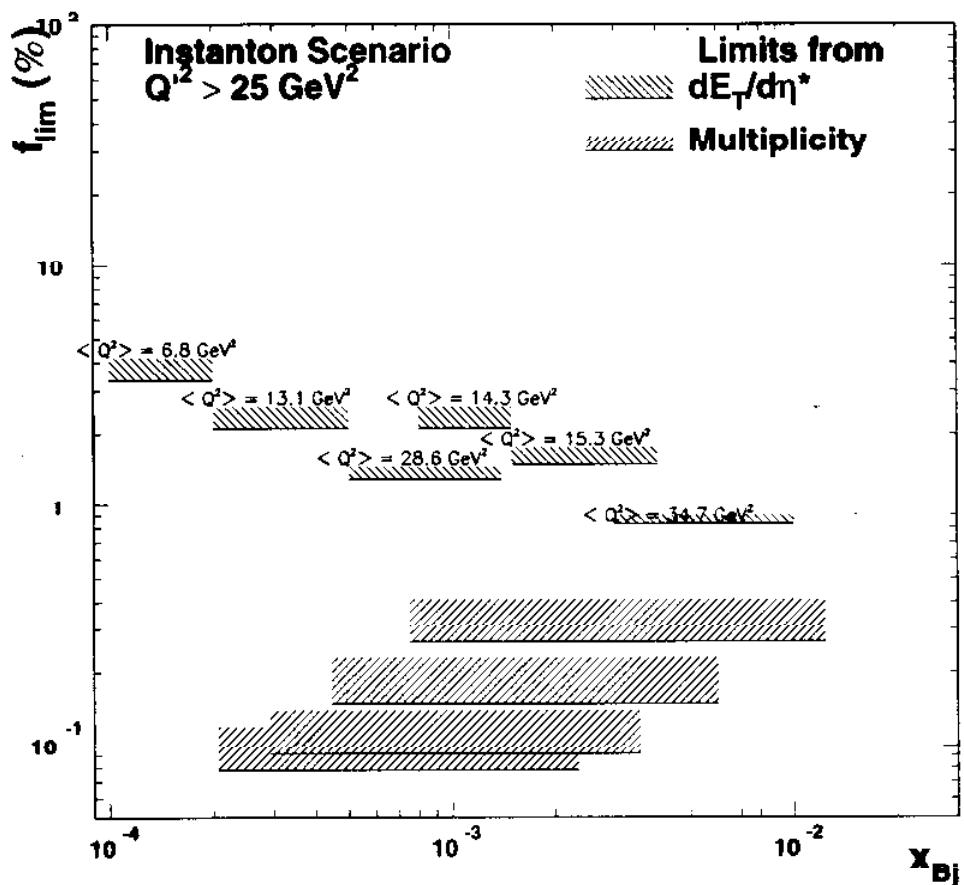
High multiplicity:

$$0.2 \lesssim f_{lim} \lesssim 0.3\% \quad 20 \lesssim \sigma_{lim} \lesssim 40 \text{ pb}$$

Maximally Allowed Instanton Fraction



Maximally Allowed Instanton Fraction



Summary

- QCD instanton production was systematically confronted to HERA data
- Most sensitive observables:
 - Transverse energy flow
 - multiplicity flow of hard particles
 - multiplicity distribution
- Extracted limits extent kinematic domain:
 $1 \cdot 10^{-4} \lesssim x_{\text{Bj}} \lesssim 1 \cdot 10^{-2}$ and $5 \lesssim Q^2 \lesssim 80 \text{ GeV}^2$
- Best limit from multiplicity distribution:

$$f_{\text{lim}} \lesssim 1\% \quad 10 \lesssim \sigma_{\text{lim}} \lesssim 60 \text{ pb}$$

Note: this limits directly scales with \mathcal{L}

- Only 1993/1994 data ($\sim 1 - 2 \text{ pb}$) were used in this analysis much more data are on tape !